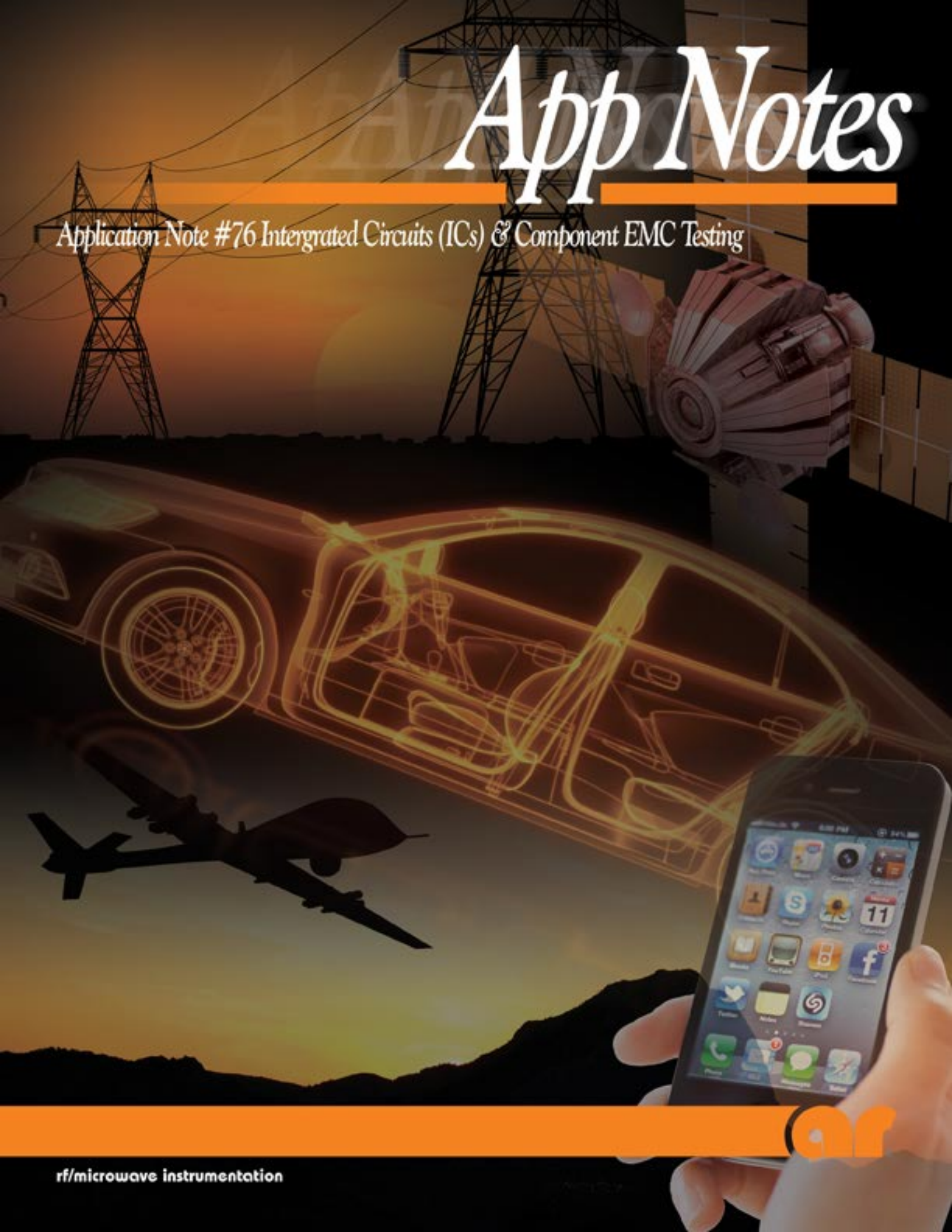


App Notes

Application Note #76 Intergrated Circuits (ICs) & Component EMC Testing



Application Note #76

Integrated Circuits (ICs) and Component EMC Testing

Can you imagine the world without Electronic devices? Today's electronic gadgets, machines and appliances have become an integral part of our lives. This is most apparent with recent developments in technology like drones, Mobile internet, medical devices, Internet of Things (IoT) and autonomous vehicles. The "core" of these amazing technologies are built with today's faster and smarter electronic components.

Due to the demand for high performing electronic devices, multi-chip package (MCP) and system-on-a-chip (SoC) technologies have become widely employed. In addition, as operating frequencies of these emerging technologies (IoT and 5G) have increased and circuits used in those technologies have become more complex, it has become impossible to ignore the large amounts of parasitic emissions generated by such complex integrated circuits (IC's).

Most IC devices operate within the Radio Frequency (RF) spectrum. When these devices co-exist with many other products, the RF spectrum becomes more congested and creates a complex electromagnetic environment. The heart or core of these electronic devices- "components" - must be hardened to operate safely and reliably in the intended electromagnetic environment. Additionally, the more electronic devices that these technologies interact and co-exist with, the greater the potential for disturbance (RF interference) among them. The largest challenge for emerging applications will be RF compliance of products and their component parts, not only with regard to regulatory requirements, but also a greater emphasis on operational environments to ensure proper performance, and public safety.

Almost every Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC) problem ultimately starts or ends at an electronic circuit. Due to the focus on energy savings and reduced power consumption, there is an increased demand for low power ICs and circuits designed with reduced supply voltages. This results in the degradation of circuit immunity levels as incident RF disturbances can easily influence a lower-power circuit. Therefore, it is required to evaluate the performance of these components for both EMI and EMC during the design stage.

If you are in the business of producing IC products that are built to operate in demanding electromagnetic environments, then you must also take precautionary measures to test and pass all the regulatory EMI and safety requirements to achieve early time to market and profitability.

So, how can one test these electronic "components" to electromagnetic fields? EMC testing is performed to ensure these components can be used in the intended environment (i.e. 5G, IoT, Drones automobiles and more) without failing, degrading or causing other equipment to fail.

The International Electrotechnical Commission (IEC) established a standard for measuring the electromagnetic interference and susceptibility to characterize ICs up to 1 GHz, IEC 62132. IEC 62132-1 provides general information on the measurement of conducted and radiated electromagnetic susceptibility. The following table provides an overview of IEC 62132 standard.

Table 1: IEC 62132 EMC test standard and some of its parts

Part of IEC 62132	Standard Title	Test Coupling to	Frequency Range & Modulation	Test Type
1	General conditions and definitions	Integrated circuits (ICs)	150 kHz - 1 GHz	NA
2	Transverse electromagnetic (TEM) cell	EUT and/or Wiring harness	150 kHz - 1 GHz 1kHz,80% AM or 100% Pulse	RI
3	Bulk current injection (BCI)	EUT Pins and Wiring harness	150 kHz - 1 GHz Idisturbance = 10 mA min.	CI
4	Direct RF power injection (DPI)	EUT Pins	150 kHz - 1 GHz 1kHz,80% AM	CI
5	Workbench Faraday cage method	EUT and/or Wiring harness	150 kHz - 1 GHz 1kHz,80% AM	CI

In a nutshell, component EMC testing addresses two categories of RF interference:

- **EMI:** Emissions testing measures RF interference that is radiated or conducted from the component. Emissions from any component can cause malfunctions in nearby components/equipment.
- **EMC:** Susceptibility testing measures the component/device's immunity to external RF interference that are conducted or radiated into the component/device.

Emissions testing confirms that the device is unlikely to interfere with other devices, while Susceptibility testing confirms that the device will keep operating despite outside interference.

The Transverse Electromagnetic (TEM) cell test method is used for measuring the emissions or immunity of an integrated circuit between 150 kHz to 1 GHz. The frequency range of this method is limited by the characteristics of the TEM cell.

Either a two-port TEM cell or a one-port TEM cell may be used. A two-port TEM cell is referred to as a TEM cell while a one-port TEM cell is referred to as a wideband Gigahertz TEM (GTEM) cell. Emissions from an EUT can be measured off these ports, or RF signals can be injected into these ports to create electric fields inside the TEM cell (Figure 1 shows the basic test set-up for TEM and GTEM cell immunity test setup).

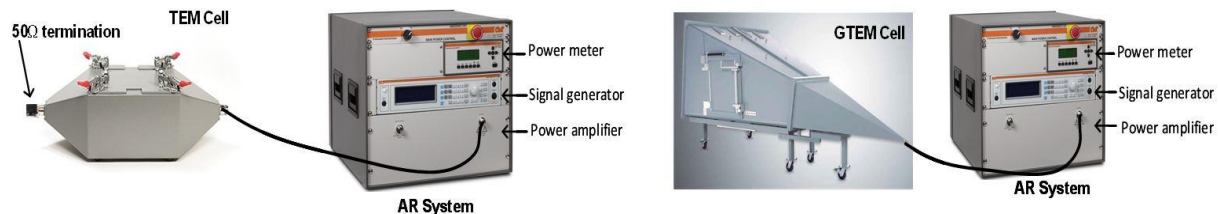


Figure 1 : TEM cell immunity test set-up

GTEM cell immunity test set-up

To reduce variations from test to test, components are mounted to special boards. The test board controls the geometry and orientation of the EUT relative to the cell and eliminates any connecting leads within the cell. Rotating the test board in the four possible orientations in the wall port of the TEM or GTEM cell is required to determine the sensitivity of the EUT to induced magnetic fields.

The injected CW or Pulse disturbance signal exposes the EUT to a plane wave electromagnetic field where the electric field component is determined by the injected voltage and the distance between the EUT and the septum of the cell. The intent of this test method is to provide a quantitative measure of the RF immunity of ICs (refer to IEC 61000-4-20 for TEM cell characteristics of RI testing). Using this method, the RF immunity of the EUT shall be evaluated at critical frequencies. Critical frequencies are frequencies that are generated by, received by, or operated by the EUT. Critical frequencies include, but are not limited to oscillator frequencies, clock frequencies, data frequencies, etc. (refer to IEC 62132-1 for more test specific requirements).

The BCI test, defined in IEC 62132-3, is a method for measuring the immunity of the IC in the presence of conducted RF disturbances. It differs from the general immunity test set-ups, as described in IEC 61967-1, requiring monitoring of output signals to determine if the IC is affected by the RF. Figure 2 shows the basic test set-up for BCI testing. Table 2 shows the frequency steps and test severity levels for BCI testing.

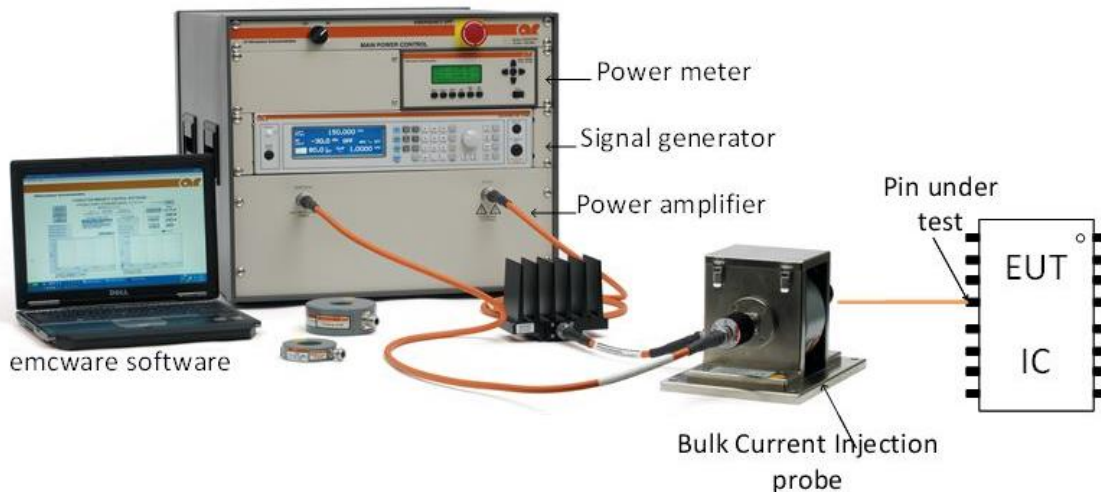


Figure 2: Basic BCI test-up

Table 2: BCI Test Frequency Steps

Frequency Band	Max Freq. Step Size(linear)	Freq.Step(Log)
10 kHz - 100 kHz	2 KHz	10%
100 kHz - 1 MHz	20 kHz	5%
1 MHz - 10 MHz	200 kHz	
10 MHz - 100 MHz	2 MHz	2%
100 MHz - 1 GHz	5 MHz	

BCI Test Severity Levels

Test Severity Levels	Current(CW value) No Insertion loss
I	50 mA
II	100 mA
III	200 mA
IV	300 mA
V	Customer specific

The bulk current injection (BCI) and direct power injection (DPI) method have become standard test methods. Because the BCI test uses a current injection probe to inject magnetically coupled electromagnetic (EM) fields, there is a significant difference between the power supplied by the radio frequency (RF) generator and that transferred to the integrated circuit (IC).

As mentioned above DPI testing is another method of EMC characterization of IC components. DPI testing measures the immunity of an integrated circuit as a function of the effective power transmitted to the circuit. However, due to impedance mismatch, most of the RF power delivered by the generator is reflected towards the source, and only a small amount enters the PCB and IC under test. To evaluate the immunity of an IC, the forward power needed to cause malfunction is measured. The malfunction may be classified from A to D according to the performance classes defined in IEC 62132-1. Figure 3 shows a typical DPI test setup.

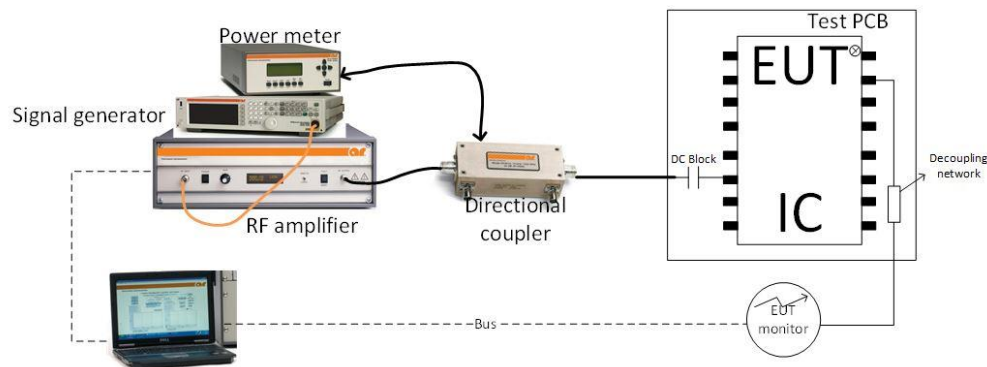


Figure 3: Basic Direct Power Injection (DPI) test-up

Many approaches have been proposed to enhance the immunity of ICs. A commonly used method is to have an IC with on-chip decoupling capacitors (RC circuit) which showed the highest immunity to RF energy. However, the actual power injected using an AR amplifier to the IC depends on the frequency of injected EM noise and the transfer characteristics of the measurement equipment, the PCB, the package, and the IC impedance. IEC 62132-3 recommends a minimum of a 50-watt linear amplifier for BCI testing to overcome these factors and deliver the necessary power to produce the required test level.

The condition whereby the output impedance of an RF amplifier differs from that of the load is said to be a “mismatch”. The extent of mismatch can be characterized in terms of Voltage Standing Wave Ratio (VSWR). In its simplest form, VSWR is the ratio of the source output impedance to the load impedance at a given frequency. AR has taken the conservative and reliable approach to design VSWR tolerant amplifiers that will operate without damage or oscillation with any magnitude and phase of the source and load impedance (see ARI app note #27A).

AR’s new U-series, 50U1000, class A, VSWR tolerant, solid-state amplifier is the product of choice of many IC manufacturers for component BCI testing. Using this new VSWR tolerant and power transfer efficient amplifier, the real injected power into the IC is achieved, and used as a reference for the new required power level to test the IC susceptibility.

The largest geometry found in an integrated circuit is the leadframe. The size of the leadframe is in the range of a few centimeters or smaller. For a frequency range below 1 GHz, this leadframe, as well as the structures on-chip, are not regarded as efficient antennas for the reception of unwanted RF

energy. It is the cable harness and/or the traces of a printed circuit board which constitute efficient antennas. Thus, an IC receives the unwanted RF energy through the pins connected to the wires of such cables. Because of this, the electromagnetic immunity of an IC can be characterized by conducted RF disturbances (i.e. RF forward power) instead of field parameters as is usually the case in module and/or system level testing.

The test levels and required forward power depend on the application of the EUT and the pin tested. The maximum forward power level of a CW (continuous wave) RF signal for testing an externally unprotected IC-pin is up to approx. 5 W (37 dBm). If the IC pin is designed to operate with external protection, then the maximum forward power level can be decreased.

IEC 62132- 4 recommends an amplifier with a higher power capability (10–50 W) than needed for the maximum forward power level (i.e. 5 W). The output impedance of the power source shall be 50 Ω (recommended VSWR <1.2:1) to absorb reflected waves and the harmonics / spurious emission of the RF power source shall be at least 20 dB below the carrier level.

AR's new U-series, class A, VSWR tolerant, solid-state amplifiers exceed the standards and IC manufacturers' requirements for direct power injection testing. Also, AR offers a wide range of highly linear solid state, VSWR tolerant class A amplifiers (A and U-Series) which are highly recommended for both BCI and DPI component testing (DPI test set up shown in figure 3). It should be noted the direct injection of RF disturbance to the IC package is very small, and often negligible compared to the disturbance injected through the connected cables(s). Hence there is the IEC 62132-5 workbench method which is derived from the IEC 61000-4-6 (see ARI app note #66). The method described assumes that supply and signal cable(s) are attached to an electrically small test board, with dimensions $\leq \lambda / 2$, i.e. 0.15 m at 1 GHz. These connected cables become the dominant antennas; the induced RF disturbance is injected to the test board via these "antennas". Using this concept, the RF performance of the circuit board layout, the IC supply decoupling, and discrete components (capacitors and inductors) can be measured.

AR's emcware provides automated EMC testing and report generation for all types of user-defined test profiles. It is configured in modules based on different types of EMC testing. Within each module, there are predefined test profiles based on EMC standard test requirements. The emcware suite is designed to be user-friendly yet extremely flexible. To make testing more flexible, it is designed to allow the user to select between manual and automatic signal routing. Automatic signal routing is implemented using up to two AR RF/Microwave Instrumentation Model SC2000 System Controllers. It is a standalone software application designed to operate on a Microsoft Windows operating system computer.

Summary:

In every product sector new emerging technologies (IoT,5G, drones, automobiles, and others) rely increasingly on highly robust and efficient electronic components for critical operation. There is a growing concern on their performance and co-existence in the presence of an electromagnetic environment. It is crucial for an integrated circuit to operate without error in the presence of relatively high RF levels, while also limiting EMI levels to avoid damage or disruption to other components within the multi-chip packages. By following the techniques outlined in this application note, and through the selection of AR's appropriate test solutions, manufacturers are able to design robust integrated chips, enabling emerging technologies to operate reliably without EMC or EMI problems. Furthermore, by using AR's emcware greater efficiency is gained, while also achieving increased quality of test results. If you would like to learn more, feel free to contact one of our applications engineers at 800-933-8181 or visit our website at www.arworld.us.